Chapter 4

TECHNOLOGICAL ASSESSMENT

Introduction

The Federal Aviation Administration (FAA) is responsible for providing the infrastructure to operate, maintain and improve the air traffic control system and otherwise manage the airspace system within the United States. Although these responsibilities represent just one area of the FAA's charge, they are the primary focus of those issues related to this study. The FAA is presently examining its mission and means to best provide for continued management of the airspace infrastructure. Terms such as communications/navigation/surveillance (CNS) and air traffic management (ATM) are mentioned with increasing regularity within the aviation industry. These elements have an impact on future actions in which a state aviation agency may elect to participate. The following sections are intended to highlight principal issues with respect to CNS/ATM and aviation support services to provide a basis for establishing and maintaining future navigational aids and services in Arizona.

Navigation

1. The introduction of global positioning system (GPS) technology for civilian aviation use in February 1994 ushered in a new mind set with respect to air navigation. Although the United States Department of Defense forces have used GPS since 1973, it was not until early 1994 that the technology was made available for civilian aviation applications. Three major driving forces supported this transition:

    1. A need to maximize the existing air navigation facilities system.

    2. Demands to reduce the cost of operating and maintaining the existing navigation system.

    3. Desires to further enhance aviation safety and capacity.

GPS is the United States' response to the International Civil Aviation Organization (ICAO) challenge of developing a primary stand-alone navigation capability through a global navigation satellite system (GNSS). GNSS builds on the United States GPS, Russian global orbiting navigation satellite system (GLONASS) and other satellite systems, as they become available. Other such systems include, for example, the European geostationary navigation overlay system (EGNOS) which is the European counterpart to WAAS (see below).

Essentially, GPS, GLONASS and other such systems use earth-orbiting satellites positioned in different orbital planes, which radiate precisely timed signals of code and navigation data. The signals are received by airborne aircraft to calculate a three-dimensional position (latitude, longitude and altitude). The GPS receiver in the aircraft typically acquires positioning data from between four and eight satellites and selects at least those four which best enable a computation of the aircraft's position. As one satellite moves from view of the aircraft receiver, a new satellite should become visible so that the receiver continues to monitor and compute its position. Ground reference stations also receive GPS satellite positioning data and because the location of these stations is precisely known, can detect errors in the satellite positioning data stream. Corrections are then uplinked to geostationary satellites that transmit the corrections to the aircraft GPS receivers.

Due to the evolutionary impact GPS has on aviation, the FAA has embarked on a deliberate program to introduce the available and planned technology in a measured fashion. An initial step was the establishment of TSO-C129, "Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)" which enabled civilian use of GPS in instrument flight rule (IFR) procedures for en route, terminal and nonprecision approaches. Depending upon the classification of the TSO-C129 GPS equipment installed in the aircraft and whether it transmits data to an integrated navigation system such as flight management system which provides enhanced guidance to an autopilot or flight director in order to reduce flight technical errors, pilots can utilize GPS for oceanic, en route, terminal and nonprecision approaches except those based on procedures using localizer (LOC), localizer-type directional aid (LDA), or simplified directional facility (SDF) equipment. A basic requirement is that the GPS equipment provide the receiver autonomous integrity monitoring (RAIM) for the procedure intended. RAIM involves the use of redundant measurements to test the validity of the received signals. RAIM obtains positioning data from at least four satellites visible to the aircraft in order to select those most appropriate for calculating the position of the aircraft. RAIM provides an integrity capability, but reduces the availability because the system is available only when redundant satellites are in view in an acceptable geometry. Should one or more satellites be malfunctioning, RAIM could not provide the reliability for navigation. When RAIM is not provided, the aircraft must fly the ground-based navigational aids (NAVAIDS) which are used to establish the procedures. This applies to flights to the destination airport. Any required alternate airport must have an approved instrument procedure and the aircraft must be able to navigate to that alternate using means other than those provided by GPS or long range navigation-C system (LORAN-C). These same regulations apply to stand-alone nonprecision GPS approach procedures.

International standards associated with civilian aviation navigation are developed by ICAO of which the FAA is an active participant. Additionally, the RTCA, Inc., an association of aeronautical organizations of the United States government and industry provides technical assistance in defining these standards. A principal output of this collaborative effort is the required navigation performance (RNP) for all phases of flight. RNP defines the navigation performance accuracy necessary for operation within a defined airspace. Measures of RNP include accuracy, integrity, availability and continuity. Accuracy is the degree of conformance of an aircraft's measured position with its true position. Integrity is the ability to provide timely warnings when part or all of the system is providing erroneous information and thus should not be used for navigation. Availability is the probability that at any time the system will meet the accuracy and integrity requirements for a specific phase of flight. Continuity is the probability that a service will continue to be available for a specified period of time and is of concern primarily in the approach phase of flight.

Because GPS with RAIM or an integrated navigation system to provide RAIM-equivalent capability cannot meet the RNP for precision approaches, the FAA is implementing a wide area augmentation system (WAAS) to permit Category I approaches (ceiling as low as 200 feet and visibility as low as ½-mile). Standards for a local area augmentation system (LAAS) are being readied to provide Category II/III approach capabilities. WAAS is intended to operate in the following sequence of events, which requires about six seconds of time:

1. The GPS satellite data is received at one of the 24 (initial) to 36 (future) wide area ground reference stations precisely located throughout the United States.

2. This data is transmitted over landlines to one or two wide area master stations that determine the integrity, differential corrections, residual error and ionospheric information for each monitored satellite.

3. The wide area corrections computed at the master station are then sent via landlines to a ground earth station which uplinks the message to one of several geostationary communications satellites.

4. The geostationary satellite then downloads this data to the WAAS receiver on the aircraft.

5. The WAAS receiver processes the integrity data to ensure that the satellites being used are providing in-tolerance data; applies the differential correction and ionoshperic information data to improve the accuracy of the aircraft's position solution; and processes the ranging data from one or more of the geostationary satellites for position determination.

WAAS meets the RNP for Category I precision approaches. However, a finer level of augmentation is necessary to comply with Category II/II RNP standards. LAAS is being designed to achieve this capability. Whereas WAAS can be considered a centralized approach in which data from the reference station is sent to a central location for processing and corrections are broadcast through communications satellites, LAAS is a distributed approach with ground stations close to the airport to which the approach is being conducted. These locations provide positioning corrections that are specific to the point of use at the airport and reduce the time for data link transmissions to the receiver in the aircraft which is coupled to the aircraft's flight management system, thereby providing greater accuracy on approach.

Interestingly, WAAS corrections are applicable at grid points and must be interpolated by aircraft software to produce the requisite positioning accuracies. The interpolation algorithms needed to compute location-specific corrections result in high complexity for airborne and ground software with attendant development and certification risks. This large software development effort also has attendant schedule risk. LAAS is a simpler technology and eliminates the need for external processing or satellite communications links. LAAS has moved more quickly into production development with several manufacturers providing the equipment. However, the FAA has yet to establish the final performance standards for LAAS and, thus, those systems being marketed will also serve as test centers for the FAA in their standard-setting process. The primary debate on standards is related to the choice of data link from the ground station to the aircraft receiver. In practice today, these pre-LAAS systems are actually established as differential GPS Special Category I Systems (SCAT-I). SCAT-I is normally developed as a private-use facility, but to not less than Category I minimums. Minimum aviation system performance standards (MASPS) have been defined by FAA and RTCA for SCAT-I application. SCAT-I systems are certified in accordance with Federal Aviation Regulations Part 171, Non-Federal Navigation Facilities. This requires that special authorization, equipment and/or training be approved before any operator is approved to conduct SCAT-I approaches. Also, these regulations require that the owner of a SCAT-I facility comply with requirements related to the operation and maintenance of the system. While intended as private-use systems, any user that can satisfy the same requirements for equipage (avionics), aircraft and crew performance can be authorized to use the SCAT-I procedure.

Due to the evolutionary process in transitioning to a totally satellite-based system with wide area and local area augmentation, it is not anticipated that SCAT-I receivers will be compatible with WAAS or LAAS equipment. Further, avionics meeting TSO-C129 standards are considered supplemental means of navigation and will not meet the standards for WAAS for en route, nonprecision or precision (Category I) navigation.

GPS Transition Planning

The transition to GPS is but one part of the FAA's overall activities involving evolutionary changes in the nation's CNS/ATM systems. Usually, long transition periods are needed when aircraft equipage changes are involved. These factors influence the introduction and staging of systems to serve the aviation community. FAA plans, while emphasizing commercial air transportation, also need to consider the large and valuable general aviation and corporate business fleet and the airports they use. To address these and related concerns, the FAA has undertaken a major effort to develop an "affordable" national airspace system architecture which is to be the roadmap of its plans and programs to the future. Present plans and schedules suggest the following scenario:

Omega System	Ends 2000
Loran System	Ends 2000
NDB Phase-out	Begins 2000; completed by 2005
VOR/NDB Phase-out	Begins 2005; completed by 2010
ILS Phase-out	Begins 2005; completed by 2010
GPS WAAS	Phase-in begins 1998; completed by 2001
GPS LAAS	Phase-in begins 2001; completed by 2006

Observations

Notwithstanding the plans and programs of the FAA, which reflect technical considerations, history has shown that technology has not been the limitation to implementation. Rather, non-technical factors have driven events. The timing of evolutionary changes in CNS is heavily dependent on federal funding, but also on the pace of decision making in the aviation community and in Congress, and the ability of the FAA to follow through on its aims and plans.

Economic factors have a major influence in the transition from a ground-based navigation system to one that relies on satellite positioning and augmentation. Although the transition in aircraft equipage can be expected to relatively progress more quickly in those aircraft used in scheduled airline and commercial service, the greater impact will be on the general aviation community. Because the nation's navigation system must accommodate all levels of users, any transition schedule must allow sufficient time for all users to participate in an economically acceptable basis. The FAA intends to provide about 10 years of dual operations until the ground-based systems are decommissioned. Inherent in this dual operations mode is the underlying fact that there be a period of time to ensure that the WAAS operates as designed. The FAA estimates that 100 percent of the general aviation executive and business fleet will be equipped with GPS WAAS receivers by 2004, about 2 years after the scheduled and air taxi fleets reach this capability level. Nearly two-thirds of the balance of the general aviation fleet will transition to this capability by 2011, by which time the demand for GPS/WAAS receivers will be sufficiently high as to become more affordable for general aviation users.

The requirement for back-up systems to a satellite-based navigation program appears to be a valid argument inasmuch as the system could be vulnerable to incidental, unintentional or intentional interference. This situation is currently under evaluation with an aim to avoid or minimize ground-based solutions. One area of investigation involves the use of the ATM and surveillance capabilities to provide flight direction information in the event of the loss of GPS service. Another means provides for the retention of a base network of VOR/VORTAC facilities or the Loran-C network.

The implications of the preceding information are that the FAA is progressing toward a primary means of navigation that will be satellite-based. The aging of the present ground-based systems and funding constraints to maintain and operate this equipment dictate that new technologies be employed to meet the demands of increasing air traffic activity. The transition period is necessarily influenced by the ability of the users to modify their aircraft equipage, including complementary components such as communications and data link features. The pace of this transition will likely be longer than outlined above because the FAA has not yet finalized all components of the architecture of a future CNS/ATM and the views of the aviation public are continuing to be expressed. It is expected that a dual operations mode will exist for the planning horizon of this study and there will be steady progress in the development of nonprecision stand-alone GPS approaches based on the WAAS. WAAS will also support Precision Category I approaches, but the implementation of this capability will require extensive field evaluations. However, in the interim, the FAA is not promoting the installation of conventional ILS facilities with grant funding. Airports justifying a precision instrument approach capability have the option of pursuing FAA funding for a conventional ILS, waiting for the confirmed implementation of WAAS, or purchasing and maintaining commercial off-the-shelf Category I ILS equipment and supporting approach lighting systems.

Transponder Landing System

The transponder landing system (TLS) has been under development and testing for several years and in May 1998 received type certification from the FAA to support Special Category I precision approach operations by aircraft equipped with standard ILS receivers and a Mode A secondary surveillance radar transponder. Operational approval is currently limited to a single aircraft on approach. The type certification is in accordance with FAR Part 171. This currently places the TLS in the same status as the SCAT-I facilities that are associated with the LAAS concept for navigation. Thus, the TLS is limited to those aircraft operators requesting authorization to conduct precision (lateral and vertical guidance) approaches to a particular airport. Similar to the GPS-derived SCAT-I procedures, the TLS can serve multiple runway ends, but at only one airport. The TLS is also subject to airport owner compliance with defined operation and maintenance procedures for the facility. The TLS thus offers another option to certain aircraft operators and airport owners desiring to have a precision approach capability.

The advantage that the TLS enjoys over a SCAT-I/LAAS solution is that the aircraft operator can utilize avionics that are relied upon to conduct traditional Category I ILS approach procedures. No new aircraft equipment is needed. The TLS operates by interrogating the aircraft on final approach through the on-board transponder. The transponder replies and is sensed by multiple ground receivers near the runway. A processor computes the position of the aircraft relative to the database approach path and flight path guidance signals are transmitted to the aircraft on localizer and glide slope frequencies. These signals are displayed on the aircraft's existing ILS indicators. The pilot or autopilot equipment can then control the aircraft position through the approach and landing.

Siting requirements for the TLS ground sensors are less demanding than those for the conventional Category I ILS facilities. This is similar to the SCAT-I/LAAS installation. Establishment costs for the TLS are comparable to those of conventional Category I ILS and SCAT-I facilities.

In summary, the TLS offers an option to airports with challenging siting conditions where a conventional Category I ILS facility may not properly function, and/or where there is a lack of suitably equipped aircraft to utilize a GPS-based SCAT-I facility. It is also better suited for low activity airports because the TLS approach is limited to one aircraft at a time.

Communications

The FAA is addressing communications requirements as part of its airspace architecture analysis and evaluation, however, many of the items of concern relate to internal FAA communications. Therefore, in the context of this study, communications issues center on air-to-ground capabilities.

Currently, air-to ground communications are for analog voice transmission only without data capability. Transmissions for civilian aviation use rely on the very high frequency (VHF) spectrum, which is presently reaching a saturation of available frequencies. The FAA created more frequencies when it deployed 25 kHz spacing for air-to-ground communications in the mid-1980's. Yet the need for additional frequency spectrum is increasing, especially in high traffic density areas. The decommissioning of ground-based NAVAIDS would allow for their associated frequencies to be reassigned, however, the operational gain might sustain operations for a few years. Consideration has been given to implementing a spacing of 8.33 kHz, but again this is expected to extend operational capability for some 10 to 12 years.

1. Coupled with this situation is the explosion in telecommunications capabilities with strong movement toward digital transmission of voice and data. Private communications systems in use by major air carriers, regional airlines and high-end general aviation/corporate aircraft are communicating with data uplink/downlink systems. Other segments of the general aviation community have expressed an interest in such systems to receive flight information services, weather updates and advisories and other in-flight information to enhance safety. Accordingly, there are a variety of alternative communications vehicles that the FAA is exploring. Among these are:

1. Continuing the current analog system while providing a separate VHF digital uplink capability.

2. Implementing a next generation communications system (NEXCOM) which would have both a digital voice and data capability and emulate the existing analog system.

3. Using 8.33 kHz voice radios together with VHF digital radios.

4. Employing low and medium earth orbit satellites.

5. Integrating voice and data over time division multiple access (TDMA) radios.

6. Using only data-only TDMA radios.

7. Using carrier sense multiple access (CSMA) radios.

As in the case of a future navigation system, the transition to a new air-to-ground communications system will be based on user acceptance of the proposed equipment and ability to absorb the establishment costs. The FAA's ability to implement and fund the intended program to meet its operational needs is another factor contributing to any schedule. It is likely that a new digital communications system will eventually be necessary if the full benefits of a future CNS/ATM program are to be achieved.

Surveillance

The need to enhance air traffic control capabilities with updated surveillance facilities is a role relegated to the FAA and not necessarily that of state governments. It is clear that the FAA will be advancing its use of current and anticipated technologies for surveillance purposes. A number of individual programs are being investigated, each with an aim to contributing to flight safety and minimizing operating costs.

Of those technologies being investigated is automatic dependent surveillance broadcast (ADS-B). The ADS-B is a transponder that provides periodic broadcast of the aircraft position, altitude, identification and other information to other similarly equipped aircraft as well as to air traffic control centers. It is a satellite-dependent system, which for air-to-air communications, can be implemented within the next three years. Data transmission to the air route traffic control centers will necessitate the establishment of ADS-B ground stations. These are expected to be phased into operation in the 2008 to 2012 timeframe. A benefit of ADS-B is its use in areas not covered by conventional radar systems, as occurs in certain areas of Arizona at low altitudes, and in oceanic airspace.

Flight Services

The FAA provides flight services through its system of automated and auxiliary flight service stations (AFSS/FSS). The AFSS/FSS provides preflight briefings with regard to navigation, airport details, and weather; opens and closes flight plans; and offers inflight weather and other support services. Pre-flight information is available by walk-up if the pilot is at the AFSS/FSS location or by telephone. The FAA also offers pre-flight services through its direct user access terminal service (DUATS) as described in Chapter 2.

The future of these services lies in their automation so that pilots may self-brief using advanced computer software capabilities including graphics. Access to a briefer will continue to be available, however, their duties will be directed more toward assisting pilots in flight. The proposed architecture for the automation enhancement program is named the operational and supportability implementation system (OASIS). One of the planned features of OASIS is to provide more, different and improved weather products and interfaces with the National Weather Service. Also included in the future is the deployment of terminals and self-service kiosks at airport locations to enhance the access and delivery of these data and products.

Federal funding limitations may lead to the continued deployment of some services by the private sector, a practice already in effect for several years with good results. DUATS is an example of a public-private partnership in the delivery of pre-flight services. However, this federally subsidized, vendor-provided service will likely be phased out as the capabilities of OASIS are implemented. There are also opportunities that state aviation agencies can explore to complement FAA initiatives and programs related to pre-flight services to the aviation community. Such options will be considered in a subsequent part of this study.